Structural Equation Modeling of Food Safety Standard in the Cassava Industry in Thailand

การใช้สมการเชิงโครงสร้าง เพื่อศึกษามาตรฐานด้านความปลอดภัยของอาหารในอุตสาหกรรมมันสำปะหลังของประเทศไทย

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ABSTRACT

Food safety is becoming more important in Thailand, especially when the country officially joins the ASEAN Economic Community (AEC) in the year 2015. In this study, key food safety factors and their associated items were mainly extracted from the two international food safety standards: the HACCP and the GMP standards. The questionnaire survey was used to collect data from cassava manufacturers for the exploratory factor analysis and the structural equation modelling. The analysis results revealed seven key factors in enhancing food safety standards: 1) Management, 2) Man, 3) Environment, 4) Material-Related, 5) Method, 6) Machine, and 7) Raw Material. The structural equation modelling results revealed causal relationships among the seven key factors. It was found that the Management factor is the most important factor in enhancing food safety standard in Thailand as it influences all other factors, both directly and indirectly. Management should, hence, set up realistic food safety policies, assign appropriate safety responsibility to the lower levels, and provide adequate necessary resources to improve food safety in the cassava industry.

ARTICLE INFO

Article history:
Received 9 June 2016
Received in revised form 8 August 2016
Accepted 16 August 2016
Available online 30 June 2017

Keywords:
Cassava
Cause and Effect Diagram
Exploratory Factor Analysis
Food Safety Standard
Structural Equation Modelling

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บทคัดย่อ

ความปลอดภัยทางอาหารเป็นหัวข้อที่มีความสำคัญในประเทศไทยในปัจจุบัน โดยเฉพาะเมื่อประเทศเข้าสู่การเป็นสมาชิกประชาคมเศรษฐกิจอาเซียน ในการศึกษานี้ ปัจจัยที่มีความสำคัญความปลอดภัยทางอาหารถูกคัดกรองมาจากมาตรฐานสากล 2 มาตรฐาน ได้แก่ HACCP และ GMP เพื่อนำไปใช้ในการออกแบบสอบถาม เก็บข้อมูลจากอุตสาหกรรมมันสำปะหลัง เพื่อนำมาใช้ในการวิเคราะห์ด้วยวิธีวิเคราะห์องค์ประกอบ (Exploratory Factor Analysis) และโมเดลสมการโครงสร้าง (Structural Equation Modeling) ผลการวิเคราะห์สรุปปัจจัยหลัก 7 ปัจจัย ได้แก่ 1. ฝ่ายบริหาร 2. พนักงาน 3. สิ่งแวดล้อม 4. วัสดุ 5. กระบวนการ 6. เครื่องจักร และ 7. วัตถุดิบ ทั้งนี้พบว่า ปัจจัยด้านฝ่ายบริหารมีความสำคัญมากที่สุดในการพัฒนามาตรฐานด้านความปลอดภัยทางอาหาร เนื่องจากเป็นปัจจัยที่มีผลกระทบต่อปัจจัยอื่น ๆ ทั้งทางตรงและทางอ้อม ดังนั้น ฝ่ายบริหารจึงควรตั้งนโยบายด้านความปลอดภัยทางอาหาร จัดสรรความรับผิดชอบให้กับพนักงาน และให้ความช่วยเหลือในด้านต่าง ๆ อย่างเหมาะสม

Introduction

Foodborne diseases take a major toll on health. Millions of people fall ill and many die as a result of eating unsafe food. Food safety encompasses actions aimed at ensuring that all food is as safe as possible (World Health Organization (WHO), 2014). In Association of Southeast Asian Nations (ASEAN) countries, the food safety standard has been adopted rapidly, with more quality tests used to show the customers that the products have been standardized and safe (Bonne, Wright, Camberou and Boccas, 2005). The phenomenon has influenced the whole region to concern more on the importance of food safety, leading to more competitive and intensive standardization of food production (Wang, Li and O'Brien, 2009).

In Thailand, food safety has become increasingly important as there are approximately a million cases of acute diarrhea reported in Thailand each year, and the reported cases of food poisoning are more than 120,000 per year (Food and Agriculture Organization of United Nations (FAO), 2004). Many entrepreneurs have been adjusting themselves accordingly to the situation of food safety concerns, resulting in more safety tests found in various food products to enhance customer satisfaction. In the cassava industry, a number of researches have been conducted in the area of food poisoning. Dufour, O'Brien and Best (2002), for example, summarized a number of cassava biotechnology research projects, specifically in the Cyanogenesis area, in Thailand. Bograd (2011) examined effects of supplemental irrigation on reducing cyanide content of various cassava types. He concluded that irrigating with 60 mm per month, and harvesting at nine months after planting guarantee the lowest gyanogenic content, and the highest starch percentage in cassava roots.

Being a part of the ASEAN Economic Community (AEC) in 2015, Thailand will open the trade border to many businesses. Food industry will be more competitive, and that the adaptation to meet the requirement for the food safety standard is needed to gain the competitive advantage. This paper, therefore, utilizes a cause and effect diagram to conceptualize key food safety factors. The exploratory factor analysis and the structural equation modelling are then employed to confirm key food safety constructs, and examine causal relationships among those key constructs. It is expected that the study results guide the industry to better understand and plan for its food safety implementation to increase the competitiveness in the AEC market.

Food Safety Standards in the AEC Countries

The ASEAN Economics Community (AEC) is the coalition of the ten countries in ASEAN: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam, to gain economic advantages similarly to the Euro zone (ASEAN Secretariat, 2014). This economic integration increases the bargaining power with other trading partners, and support free trading for some products among member countries, except for sensitive products requested by each country.

Many food safety standards are implemented in the AEC countries (see Table 1); major food safety standards implemented are the Hazard Analysis Critical Control Point (HACCP) and the Good Manufacturing Practice (GMP) standards (Ramos and Oblepias, 2002; FAO, 2004; Ministry of Health, Laos, 2009; Thailand Board of Investment, 2010; Dao, Huong and Boone, 2011; Chia, 2012; Sphere Exhibits Malaysia, 2013).

Table 1. Food safety standards in the AEC countries

Country	Food Safety Standard											
	BRC	**GAP**	**GHP**	**GMO**	**GMP**	**HALAL**	**HACCP**	**ISO 9000**	**ISO 9001**	**ISO 22000**	**TQM**	**Total**
Brunei					/		/			/		3
Cambodia					/		/					2
Indonesia					/	/	/		/			4
Laos		/	/		/		/					4
Malaysia			/		/	/	/	/				5
Myanmar					/		/					2
Philippines					/		/					2
Singapore	/				/	/	/			/		5
Thailand				/	/		/			/	/	5
Vietnam					/		/					2
Total	1	1	2	1	10	3	10	1	1	3	1	

The HACCP standard is the analysis system of danger and critical point that needs to be controlled (Schmidt and Newslow, 2013). The system is used as the tool to identify, evaluate, and control the biological, chemical, and physical hazards that may occur in food products. It is internationally accepted to be effective in assuring the safety of food for customers, as it is designed to detect and control the hazard at the exact point of production that has the tendency to cause harm (Schmidt and Newslow, 2013).

The GMP standard, on the other hand, focuses on preventing the risks that may make the food hazardous or cause harm to consumers (Schmidt and Newslow, 2013). It contains the general standard that details basic regulations that are applied to all kinds of food products, and the specific standard that focuses on the specific risks and safety of some particular products (Schmidt and Newslow, 2013).

The above two standards are used to develop a cause and effect diagram to extract key factors necessary to improve safety standard in the food industry.

Cause and Effect Diagram of Food Safety Standard

Cause and effect diagram, also known as fishbone or Ishikawa diagram, is an effective tool to be used as a guideline to improve food safety standard (Bose, 2012). It is a tool for analysing the business process and its effectiveness. It evaluates the causes and sub-causes of one particular problem, and therefore assists to uncover all the symptoms of any business problem.

The main problem, which is required to be resolved, has been put on the head of the diagram, and the causes are put as the bones (Balance Scorecard Institute, 2007). The smaller bones are created as the resemblances of the sub-causes. Ultimately, after completion of the diagram, it is a comprehensive evaluation of the causes of the main problems, and reveals all possible root causes.

According to Bose (2012), a fishbone diagram consists of six factors: people (man), materials, equipment (machine), process (method), management, and environment (see Figure 1). This is consistent with Pandey (2007) who commented that these six factors are crucial in the supply chain management in the service industry.

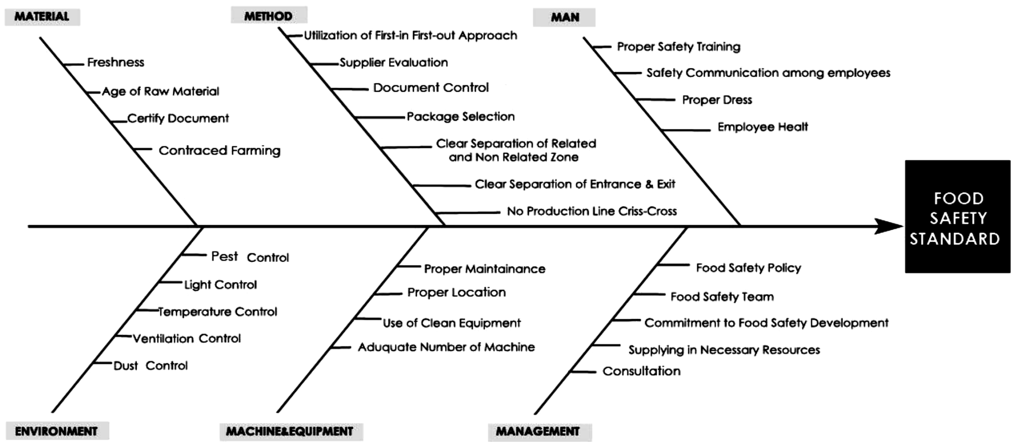

Figure 1. An example of a cause and effect diagram

In this study, the six key factors are used to better understand and plan for food safety implementation. Items associated with each key factor are extracted from the HACCP and GMP standards, as well as, other food safety-related literature (see Figure 1).

- Man factor: This factor consists of four items: 1) proper safety training, 2) safety communication among employees, 3) proper dress, and 4) employee health (Bonne et al., 2005; Thai Industrial Standard, 2005; Agri-food and Veterinary Authority of Singapore (AVA), 2013; Khrais, Al-Araidah, Aweisi, Elias and Al-Ayyoub, 2013).
- Material factor: It consists of four items: 1) freshness, 2) age of raw material, 3) certified document of raw cassava, and 4) contract farming (Dziedzoave, Abass, Amoa-Awua and Sablah, 2006; Parthanadee, Buddhakulsomsiri, Monthatipkul and Khompatraporn, 2010; Schmidt and Newslow, 2013).
- Method factor: This factor is associated with seven items, including 1) utilization of first in first out approach, 2) supplier evaluation, 3) document control, 4) package selection, 5) clear separation of related of non-related zones, 6) clear separation of entrance and exit, and 7) no production line criss-cross (Bonne et al., 2005; Thai Industrial Standard Institute, 2005; Confederation of European Paper Industries (CEPI), 2010; AVA, 2013).
- Machine factor: This factor consists of four items, namely 1) proper maintenance, 2) proper location, 3) use of clean machine, and 4) adequate number of machines (Bonne et al., 2005; Thai Industrial Standards Institute, 2005; Easdani and Bhuiyan, 2012).

- Management factor: This factor is associated with five items: 1) food safety policy, 2) commitment to food safety development, 3) food safety team, 4) supplying in necessary resources, and 5) consultation (Thai Industrial Standard, 2005; Aronson, Reilly and Lynn, 2006; Dundes and Swann, 2008; Khrais et al., 2013).
- Environment factor: This factor is associated with five items, namely 1) pest control, 2) light control, 3) temperature control, 4) ventilation control, and 5) dust control (Bonne et al., 2005; Dundes and Swann, 2008; Rider, Aken, Sman, Mason and Chen, 2009; Berry, McNeely, Beauregard and Geddie, 2012).

A total of 29 items, within six key factors, are used to develop questionnaire survey to gather data for further analyses.

Questionnaire Survey and Data Screening

The questionnaire survey is used in this study to gather data from the cassava manufacturers. According to Royal Thai Government (2014), Thailand has been the world's leading cassava exporting country for the past 50 years. More than half of the product yield is exported to China, ASEAN countries, Europe, and America, There is also an increase in world demand for cassava, as it is available for sale in a wider range of format, including animal feed and using cassava as alternative energy source.

A list of cassava manufacturers located mainly in North Eastern part of Thailand is used as a sampling frame. The target group is the manufacturers of starch as it is one of the major cassava products (Treesilvattanakul, 2015). Both lower and higher working levels, such as managers, engineers, project supervisors, and frontline employees, are selected as the target respondents to gain mixed perceptions of food safety in the organization.

The questionnaire survey comprises three parts. The first part aims to gather demographical information about the respondents and their respective organizations to ensure their appropriate background. The second part covers 29 statements to define six key food safety factors. The respondents are asked to score each statement using a five-point Likert scale, with point 1 representing 'strongly disagree' and point 5 representing 'strongly agree'. The scores achieved from this part are later used with the exploratory factor analysis and the structural equation modeling to confirm the key factors and examine their causal relationships. The last part collects comments and recommendations from the respondents in terms of food safety standards in Thailand.

A total of 280 surveys were sent to 28 manufacturers, with 119 responses return, representing 42.5% of the response rate. On average, seven responses are received per one manufacturer. Normality test was then performed to screen the data. Two important components of normality are skewness and kurtosis (Tabachnick and Fidell, 2014). Skewness relates to the symmetry of the distribution; a skewed variable is a variable whose mean is not in the centre of the distribution. Kurtosis, on the other hand, relates to the peakedness of a distribution; a distribution is either too peaked (with short, thick tails), or too flat (with long, thin tails). When a distribution is normal, the values of skewness and kurtosis are zero (Pallant, 2005). If there is a positive skewness, there is a pileup of cases to the left, and the right tail is too long; with negative skewness, the result is reversed. Kurtosis values above zero indicate a distribution that is too peaked, while kurtosis values below zero are reversed. Non-normal kurtosis produces an underestimate of the variance of a variable. According to Curran et al. (1996), the values of skewness $< \pm 2$ and kurtosis $< \pm 7$ are considered acceptable.

The results showed that there are no skewness and kurtosis values that exceed the limits, thus concluding the normal distribution of all the 29 items (Curran, West and Finch, 1996). The outlier test was also conducted, using a boxplot, to detect the outliers (Tabachnick and Fidell, 2014). The results led to the deletion of two sets of data, resulting in the remaining 117 data sets for further analyses.

Exploratory Factor Analysis

The 117 screened data sets were next performed with the exploratory factor analysis, using the Statistical Package for Social Sciences (SPSS) software, to confirm six key food safety factors. The SPSS software is a Windows based program that can be used to perform data entry and analysis, and create tables and graphs (The University of Vermont, 2016). It is capable of handling large amounts of data, and is commonly used in social sciences studies.

In this study, the principal axis factoring, the varimax rotation method, and a cut-off factor loading of 0.4 were used to examine the dimensionality of the 29 items within the six factors (Mahmoud and Kamel, 2010; Dowlatshahi, 2011). The loading of 0.4 is considered based on the sample size stated in Mahmoud and Kamel (2010).

The first run removed two items (the “supplier evaluation” and the “adequate number of machines” items) as they had factor loading of less than 0.4. The remaining 27 items were extracted into six factors, as shown in Table 2.

Table 2. The exploratory factor analysis results of the remaining 27 items

Item	Factor Loading					
	1	2	3	4	5	6
Food safety team	0.78					
Consultation	0.77					
Supplying in necessary resources	0.77					
Commitment to food safety development	0.74					
Food safety policy	0.71					
No production line criss-cross	0.54					
Document control	0.50					
Employee health		0.82				
Proper dress		0.75				
Safety communication among employees		0.70				
Proper safety training		0.66				
Temperature control			0.78			
Light control			0.73			
Ventilation control			0.70			
Pest control			0.43			
Contract farming				0.74		
Certified document of raw cassava				0.66		
Dust control				0.55		
Clear separation of entrance and exit					0.64	
Clear separation of related of non-relate zones					0.52	
Package selection					0.43	
Utilization of first in first out approach					0.42	
Proper maintenance						0.78
Freshness						0.69
Age of raw material						0.50
Proper location						0.49
Use of clean machine						0.47

Factor 1 was accounted by seven items mainly explaining management factor, so it was called Management factor. Factor 2 was predominantly accounted by four items, measuring Man factor. Factor 3 was associated with four items explaining the Environment factor. Factor 4 was associated with three items, and was called the Material-Related factor. Factor 5 was predominantly accounted by four items, measuring Method factor.

Factor 6 was accounted by five items, measuring machine and material factors. Closer examination of this factor revealed potential for further analysis to confirm its construct. Accordingly, it was decided to further factor-analyze the five items with the exploratory factor analysis, by setting their required extraction limit to two new factors. As a result, this factor gave rise to two new factors. The first factor consists of three associated items explaining mainly about machine used, therefore, it is named the Machine factor. The second factor extracted is associated with two items, and is called the Raw Material factor.

In summary, a total of seven food safety factors were extracted, see Table 3 and Figure 2. To further confirm these extracted factors with their associated items, the reliability test was performed. Based on Santos (1999), the Cronbach's alpha value of 0.6 is accepted as the minimum desired value of reliability. The results, as shown in Table 4, had values ranging from 0.65 to 0.94, all of which were considered reliable. This, thus, increases confidence in the contribution of the 27 items to the measurement of their respective constructs.

Table 3. Seven factors extracted from the exploratory factor analysis

Item	Factor Loading						
	Management	Man	Environment	Material-Related	Method	Machine	Raw Material
Food safety team	0.78						
Consultation	0.77						
Supplying in necessary resources	0.77						
Commitment to food safety development	0.74						
Food safety policy	0.71						
No production line criss-cross	0.54						
Document control	0.50						

Table 3. Seven factors extracted from the exploratory factor analysis (cons.)

Item	Factor Loading						
	Management	Man	Environment	Material-Related	Method	Machine	Raw Material
Employee health		0.82					
Proper dress		0.75					
Safety communication among employees		0.70					
Proper safety training		0.66					
Temperature control			0.78				
Light control			0.73				
Ventilation control			0.70				
Pest control			0.43				
Contract farming				0.74			
Certified document of raw cassava				0.66			
Dust control				0.55			
Clear separation of entrance and exit					0.64		
Clear separation of related of non-relate zones					0.52		
Package selection					0.43		
Utilization of first in first out approach					0.42		
Use of clean machine						0.65	
Proper location						0.56	
Proper maintenance						0.53	
Freshness							0.63
Age of raw material							0.52

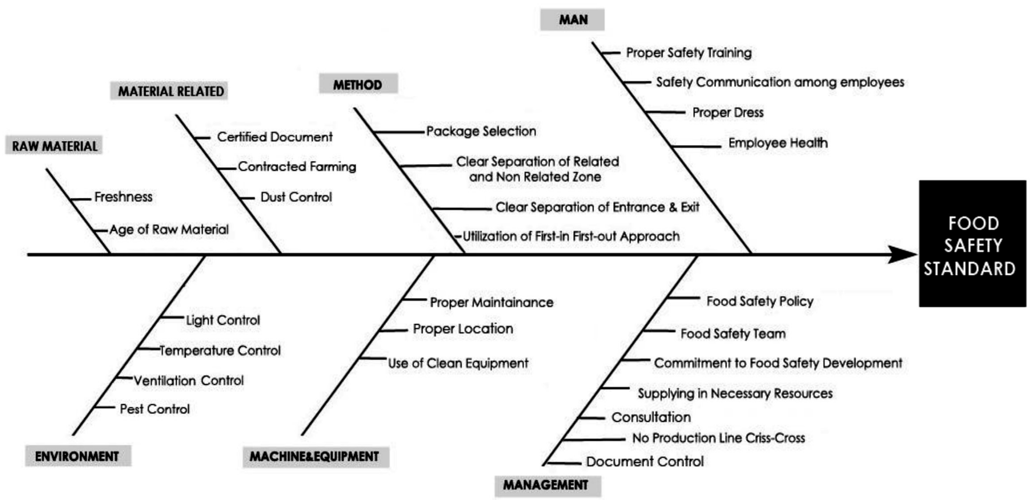

Figure 2. Seven factors of food safety standard

Table 4. The reliability test results of the seven food safety factors

Factor	Cronbach's Alpha Value
Management	0.93
Man	0.90
Environment	0.85
Material-Related	0.64
Method	0.77
Machine	0.80
Raw Material	0.61

Structural Equation Modelling

The confirmed factors are further examined with the structural equation modeling (SEM) method, utilizing the Analysis of Moment Structures (AMOS) software to investigate the causal relationships among the seven factors extracted. The AMOS software is an added SPSS module, and is specially used for structural equation modeling, path analysis, and confirmatory factor analysis. It is also known as analysis of covariance or causal modeling software (Statistics Solution, 2016).

To perform the SEM, two models are required: the measurement and the structural models (Vinodh and Joy, 2012; Jiao, Alon, Koo and Cui, 2013). Measurement model explains the relationships between factors and their items, while the structural model defines causal relationships among those factors (Jitlung, 2009). Common fit indices used in measuring model fit are chi-square per degree of freedom (CMIN/DF), root mean square error of approximation (RMSEA), and comparative fit index (CFI) (Nair and Prajogo, 2009; Kohn, McGinnis and Kara, 2011).

The CMIN/DF indicates the difference between observed and expected covariance matrices. The RMSEA avoids issues of sample size by analysing the discrepancy between the hypothesized model, with optimally chosen parameter estimates, and the population covariance matrix. The CFI analyses the model fit by examining the discrepancy between the data and the hypothesized model, while adjusting for the issues of sample size inherent in the chi-squared test of model fit, and the normed fit index. The value of CMIN/DF of less than two, RMSEA of 0.1 or less, and CFI of at least 0.9 represent a good model fit (Browne and Cudeck, 1993; Akgunb and Lynn, 2002; Tabachnick and Fidell, 2014; Kohn et al., 2011).

The measurement model of the seven factors or food safety (see Figure 3) were analyzed, and the results are illustrated in Table 5. The fit indices revealed a need to modify the model to further improve the model fit. The items shown by the computed modification indices as having multicollinearity are removed. As a result, the “pest control” item (in the Environment factor) was deleted, leading to the best-fit measurement model with the fit indices as shown in Table 5.

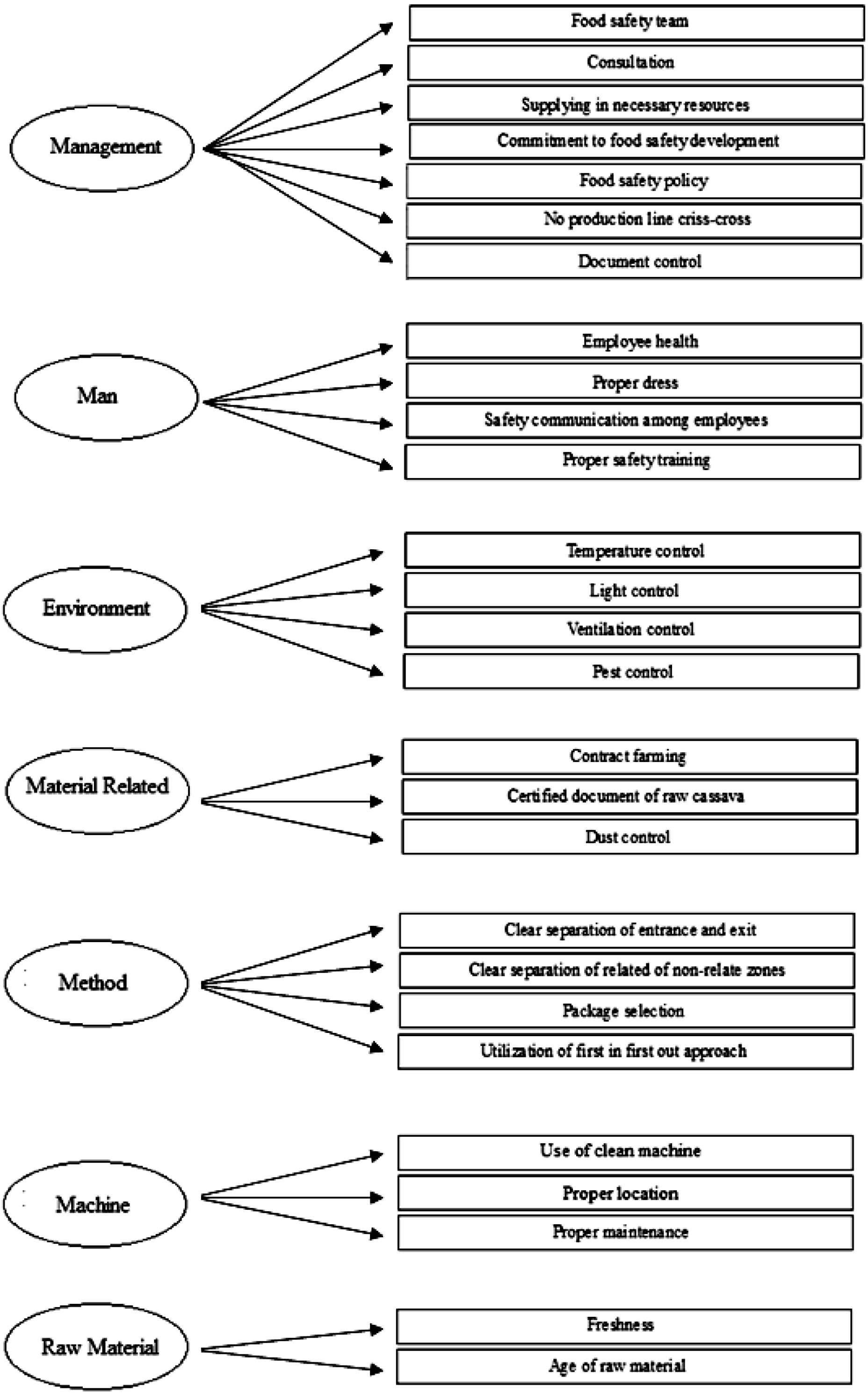

Figure 3. The measurement model of food safety standard

Table 5. Fit indices of the measurement and structural models

Fit Index	Acceptable Level	Measurement Model	Best-fit Measurement Model	Structural Model	Best-fit Structural Model
CMIN/DF	≤ 2.00	1.89	1.64	2.10	1.63
RMSEA	≤ 0.10	0.09	0.08	0.10	0.07
CFI	≥ 0.90	0.89	0.90	0.85	0.91

Note: CMIN/DF = chi-square per degree of freedom, RMSEA = root mean square error of approximation, and CFI = comparative fit index

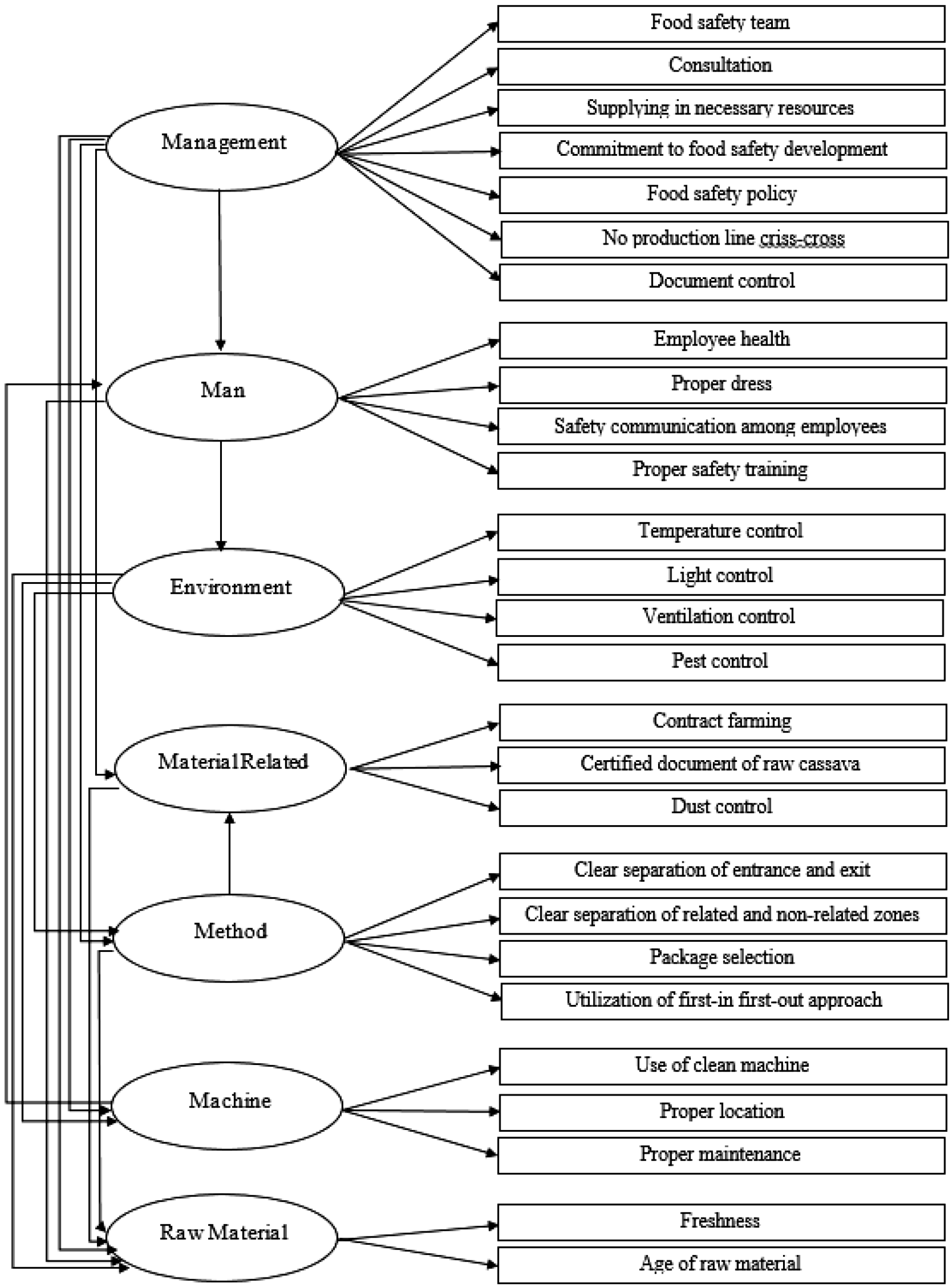

Figure 4. The structural model of food safety standard.

To further examine the directions of relationships between the seven food safety factors, the structural model was performed. Based on a number of food safety-related literatures, the assumed relationships among the key factors are as shown in Figure 4 (Bonne et al., 2005; Thai Industrial Standard, 2005; Schmidt and Newslow, 2013; AVA, 2013). The model was analyzed, and the model fit was illustrated in Table 5.

Similarly, links with low correlations, and items representing the multicollinearity were deleted. For each run, goodness of fit indices were computed and compared. According to Clissold (2004), the model with the best fit should prove the directional influences. The best-fit structural model and the fit indices are as shown in Figure 5 and Table 5.

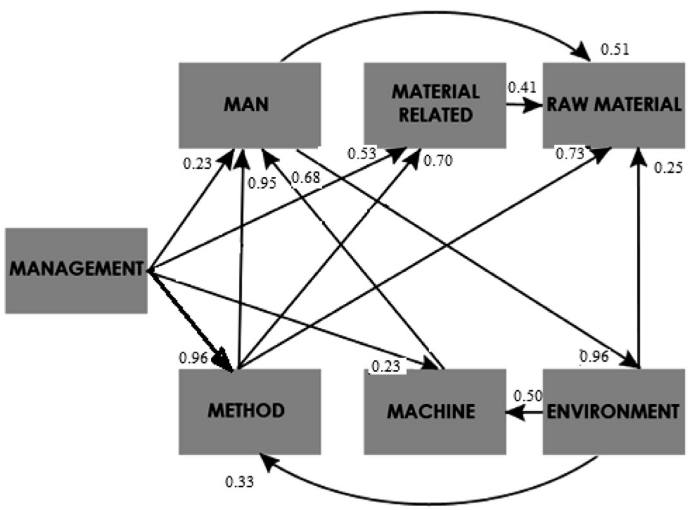

Figure 5. The best-fit structural model of food safety standard

The best-fit structural model indicates that the Management factor is the most important factor as it influences almost all other factors. This is confirmed by FAO (2016) that one of the global cassava development strategies is to be management-intensive (the "commitment to food safety development" item), not business as usual. It is found that the Management factor has a significant direct relationship with the Method factor (with path coefficient = 0.96), and indirect relationships with the Man, the Material Related, and the Raw Material factors through the Method factor (see Figure 6). This is consistent with Thai Industrial Standard (2005) that a realistic food safety policy (the "food safety policy" item in the Management factor) assists in establishing a practical implementation plan (the Method factor); this in turn enhances safety communication among the employees (the "safety communication among employees" item in the Man factor). A practical food safety plan (the "food safety policy" item in the Management factor) also helps in acquiring good quality materials for the production (the Raw Material factor) (Dziedzoave et al., 2006). Treesilvattanakul (2015) also mentioned that a supportive policy from management and government (the "food safety policy" item in the Management factor) can partly make Thai cassava farming becomes more attractive (the Material Related factor), resulting in an increase in harvested area, and consequently in cassava supply.

The Man factor has a strong relationship with the Environment factor (path coefficient = 0.96). Employee health (an item in the Man factor), for example, is vital in achieving food safety. Employees, whose diseases are likely to be transmitted to the food, must be excluded from the workplace. A well designed ventilating and air-conditioning system (the Environment factor) provides conditions for manufacturing quality products (Bonne et al., 2005; WHO, 2014).

The Material Related factor is found having a positive impact on the Raw Material factor. Cooperating with farms who have certified document, such as Good Agricultural Practices (GAP), can guarantee quality of raw materials (Parthanadee et al., 2010).

Conclusion

Thailand now focuses on improving food safety standard to be able to compete with other AEC countries. This study utilizes a cause and effect diagram of food safety standard to identify six key food safety factors, namely the Man, Material, Method, Machine, Management, and Environment factors, as well as their 29 associated items. The exploratory factor analysis is then performed to confirm the key constructs of food safety standard. The analysis results confirm seven key food safety factors, with the original Material factor extracted into two new factors, namely the Raw Material and the Material-Related factors.

Causal relationships between the seven key factors are examined through the structural equation modelling. The results reveal the Management factor as a key factor in enhancing food safety standard in the cassava industry in Thailand. This factor has significant direct relationships with the Method, Man, Material-Related, and Machine factors. Management should, therefore, commit in improving food safety by setting up realistic food safety rules, building a food safety team to monitor food safety implementation, and providing adequate necessary resources to improve food safety.

The Method factor is another key food safety factor, as it directly impacts the Man, Material-Related, and Raw Material factors. With a clear and practical guideline, employees tend to participate more on food safety implementation, resulting in good quality materials and products.

This research study was conducted using data from cassava firms in Thailand, which is considered a developing country. A comparative study, thus, may further be performed between developed and developing countries, as a future study, to investigate the differences in food safety standard and implementation.

Acknowledgement

The authors would like to thank the Thammasat University Research Fund, academic year 2013, for the financial support of the research project.

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